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# Vegetative approach for improving the quality of water produced from soils in the westside of central California

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## Abstract

Water reuse is a proposed strategy for utilizing or disposing of poor quality drainage water produced in the westside of central California. This 2-year field study evaluated the ability of two potential forage species to tolerate irrigation with water high in salinity, boron (B), and selenium (Se). The species used were: *Sporobulus airoides* var. salado (alkali sacaton) and *Medicago sativa* var. salado (alfalfa). After first year establishment with good quality water ($<$1 dS m$^{-1}$), the two species were furrow-irrigated with drainage effluent that had an average composition of sulfate-dominated salinity ((electrical conductivity (EC) of 6.2 dS m$^{-1}$)) B (5 mg l$^{-1}$), and Se (0.245 mg l$^{-1}$). Both crops were clipped monthly from June to October of each year. Total dry matter yields averaged between 11 and 12 mg ha$^{-1}$ for both crops irrigated with effluent for two growing seasons. Plant concentrations of Se ranged from a low of 1.3 mg kg$^{-1}$ in alkali sacaton to a high of 2.5 mg kg$^{-1}$ in alfalfa, while B concentrations ranged from a low of 60 mg kg$^{-1}$ in alkali sacaton to a high of 170 mg kg$^{-1}$ in alfalfa. Chemical composition of the soil changed as follows from preplant to post-irrigation after two seasons with drainage effluent: EC from 2.78 to 6.5 dS m$^{-1}$, extractable B from 1.9 to 5.6 mg l$^{-1}$, and no change in extractable Se at 0.012 mg l$^{-1}$ between 0 and 45 cm. Between 45 and 90 cm, EC values increased from 4.95 to 6.79 dS m$^{-1}$, extractable B from 2.5 to 4.8 mg l$^{-1}$, and no change in extractable Se at 0.016 mg l$^{-1}$. Increased salinity and extractable B levels in the soil indicate that management of soil salinity and B will be necessary over time to sustain long term reuse with poor quality water.

## Introduction

Expansion of agricultural production will become increasingly dependent upon expanding new supplies for irrigation. Water availability for irrigation could be enhanced through the judicious and proper use of saline drainage water. Many drainage waters can be used successfully to grow crops without long-term hazardous consequences to some crops or soils. The composition of the drainage effluent will however determine whether any of the dissolved salts are specifically toxic to plants or to the ecosystem at high concentrations (Parker et al., 1991; San Joaquin Valley Drainage Program, 1990). In this regard, drainage water produced in the San Joaquin Valley of California can contain unusually high levels of B (6–10 mg l$^{-1}$), as well as high levels of Se (100–200 $\mu$g l$^{-1}$), and salinity (5–8 dS m$^{-1}$). Since B is adsorbed by the soil, B applied to soil with irrigation water requires longer to buildup to toxic levels in the soil, and hence requires more leaching to remove excessive accumulations than does salinity. Thus, the long-term accumulation of potential toxicants, e.g., B, in the soil must be considered when using some poor quality effluents, since toxic effects may not become evident for years and may be more difficult to eliminate.

Selenium is another element of particular concern for drainage water reuse. If effluents containing Se are discharged into channels, lakes, ponds, or into other bodies of water, there are ecological concerns that Se may concentrate as it moves up the food chain at toxic levels (Ohlendorf and Hothem, 1995; Ohlendorf et al.,1986). Without a means of safely disposing of Se laden drainage water, irrigated agricultural soils pro-

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ducing such an effluent will be retired and taken out of production (Ohlendorf and Santolo, 1994).

Several strategies to utilize or dispose of drainage effluent containing Se have been proposed by the Salinity Drainage Task Force Committee in California (UC Salinity Drainage Program, 1998) and most recently evaluated by the California Department of Water Resources (California Department of Water Resources, 2001). One of these practical strategies included disposing of drainage water on salt and B tolerant crops and trees; a system known as the Integrated on Farm Drainage Management (IFDM) System (Cervinka, 1994). In this practice different types of crops are systematically irrigated with drainage water of different qualities. Crops that accumulate large quantities of B, Cl, and Na should be avoided when irrigating with saline drainage waters containing such elements.

Among the relevant crops to consider, forage crops that are salt and B tolerant may be suitable recipients for drainage water reuse. They consume high quantities of water and have an economical use for dairy and livestock industries. Identifying low-maintenance forage crops is an objective for drainage water reuse strategies, especially when pasture irrigation has been disfavored in California due to both increasing water costs and competition by urban expansion. Effluents produced in central California often contain high concentrations of both sulfate and Se. Sulfate's inhibiting effect on Se uptake should keep plant Se concentrations to non-toxic levels in forage tissue (Bell et al., 1992). Producing forage with low levels of Se and incorporating it into mixed diets may provide animal growers in selenized areas with a valuable resource produced from Se-laden saline water.

Field study evaluations are essential for determining the sustainability and productivity of any potential forage crop irrigated with Se-laden effluent. The objective of this field study was to evaluate both plant growth and trace element accumulation of a forage legume (*Salado* alfalfa) and a potential forage grass (alkali sacaton) and monitor chemical composition of the soil after irrigating with drainage effluent for 2 years. Identifying adaptable forage plant species for the disposal of poor quality waters will have practical application for arid regions of the western US where saline water containing B and Se needs to be safely disposed.

## Materials and methods

The drainage water reuse project was located in the Broadview Water District in the westside of central California (Firebaugh, CA). The 2.5-ha field plot is on soil classified as Oxalis silty clay loam with a well-developed profile. The entire field is drained by a subsurface drainage tile system that was installed at a depth of 3 m below the soil surface. The tiles were spaced in length at 300-m intervals. Nine access tubes were randomly installed to a depth of 3 m to periodically monitor the depth of the water table throughout the plot. In June of 1998, alkali sacaton (*Sporobulus airoides* var. salado) was mixed with rice hulls (1:3) and drilled on 100 cm beds at a rate of 6 kg ha$^{-1}$ on 1.5 ha and Salado alfalfa (*Medicago sativa* var. salado) was drilled in at a rate of 15 kg ha$^{-1}$ on 1.0 ha. General weather data from 15 June to 15 October 1999 and 2000 were as follows: maximum and minimum temperatures of 31 and 13°C and 31 and 14°C, respectively; total rainfall of 10 and 29 mm, respectively; and total Et$_o$ losses of 806 and 783 mm, respectively.

Both species were sprinkler-irrigated with canal water (<1 dS m$^{-1}$) to initiate germination and to establish plants prior to irrigation with saline drainage water. After emergence, plants were furrow-irrigated with canal water for one growing season (15 June to 15 October) in 1998. The Se-laden drainage water that was collected from adjacent field sites within the 'water district', was pumped from underlying drainage sumps, and applied as needed from March to September of 1999 and 2000. Total drainage water applied by furrow irrigation was 19 244 and 23 685 m$^3$ha$^{-1}$ in 1999 and 2000, respectively. Irrigation was scheduled to equal or exceed reported Et$_c$ losses for reference grass reported by the local California Irrigation Management Information System (CIMIS) weather station (Howell et al., 1984) by at least 25%. Additional effluent was not applied from 15 October to 15 March of each year, because both forage species were dormant. The average chemical composition of the drainage water is presented in Table 1.

Twenty-four soil cores were collected in a grid system from depths of 0–45 and 45–90 cm at the beginning of each growing season (15 March) and at the designated end of each growing season (15 October), respectively. Within 14 days soluble Se, B, soil EC, and pH were measured in saturated soil extract (1:1). In preparation for the determination of total Se and B in the soil, soil was screened clean of any plant

*Table 1.* Chemical composition (mg $l^{-1}$) of canal and drainage water used for irrigating *Salado* alfalfa and alkali sacaton during 1999 and 2000 growing seasons[a]

| Water source | Ca | Mg | K | Na | B | Se | Cl | $SO_4$ | $NO_3$ | pH | Ec dS $m^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Canal | 28 | 18 | 3 | 46 | 0.6 | ND[b] | 40 | 30 | 1 | 7.2 | 0.8 |
| | (4) | (2) | (0.1) | (6) | (0.1) | NA[c] | (5) | (4) | (0.1) | (0.1) | (0.1) |
| Drainage | 405 | 243 | 8 | 961 | 5 | 0.245 | 800 | 2000 | 11 | 7.8 | 6.2 |
| | (17) | (10) | (1) | (26) | (0.5) | (0.1) | (25) | (116) | (1) | (0.1) | (0.3) |

[a] Average values and standard error in parenthesis in water samples collected throughout both years.
[b] ND – not detectable.
[c] NA – not applicable.

*Table 2.* Selected chemical properties of the soil (0–90 cm) in 1998 prior to irrigation with drainage water

| | | Concentrations (mg $kg^{-1}$) of: | | | |
|---|---|---|---|---|---|
| Soil pH | Soil Ec (dS $m^{-1}$) | Total Se | Ext. Se | Total B | Ext. B |
| 0–45 cm | | | | | |
| 8.12[a] | 2.78 | 0.70 | 0.012 | 42 | 1.9 |
| (0.16) | (0.18) | (0.04) | (0) | (3) | (0.22) |
| 45–90 cm | | | | | |
| 8.06 | 4.95 | 0.71 | 0.016 | 44 | 2.5 |
| (0.13) | (0.10) | (0.03) | (0) | (2) | (0.02) |

[a] Values are the means from 24 samples with the standard error in parenthesis for each depth.

material, oven-dried at 45 C for 5 days, pulverized, and then passed through a nonmetallic 1-mm cheesecloth. Soil samples (0.5 g) were then transferred to digestion tubes, acid digested by the $HNO_3/H_2O_2$ procedure described by Bañuelos and Meek (1990), and analyzed for total Se by atomic absorption with continuous hydride generation and total B by inductively coupled plasma spectrometry (Perkin-Elmer Plasma 2000 Emission Spectrometer); generally, measures of total B concentrations in soils are poor indicators of plant available B and B supplying capacity of the soil. The National Institute Standard Reference Materials (SRM 1633; Se content of 10.3 ± 0.6 mg $kg^{-1}$, with a recovery of 92%) was used as an external quality control standard for Se analyses. The Model 160 Conductivity/Salinity Meter was used for measurement of soil EC. The general chemical properties of the soil prior to irrigation with drainage water are presented in Table 2.

Both plant species were clipped monthly from June to October to a height of 15–20 cm in four 1-$m^2$ areas randomly selected from field plots of each respective crop. Shoot samples were washed with deionized water, oven-dried at 50°C (for 7 days), weighed and ground in a stainless steel Wiley mill equipped with a 0.83-mm screen. After wet-acid digestion (Banuelos and Akohoue, 1994) plant B and Se were determined similarly as soils. The NIST wheat flour (SRM 1567, 1.1 ± 0.2 mg $kg^{-1}$ with a recovery of 93%) and apple leaf (SRM 1515, 27 ± 1 mg $kg^{-1}$) were used as an external quality control standards for Se and B analyses, respectively. Descriptive statistics were conducted and the different treatment means were compared at the probability level of $P<0.05$ by using NCSS (2000).

A mass balance was not estimated because it was not the intent of this research to grow crops for removing those trace elements that were applied to the soils with the irrigation of drainage effluent.

## Results and discussion

Growing perennial vegetation *Salado* alfalfa and alkali sacaton in the Westside of central California has manifold benefits to growers with drainage water to dispose. Because soils in this region are comprised of seleniferous Cretaceous marine sedimentary strata (Presser, 1994), irrigated agriculture on these soils produces saline effluents high in B and Se (Shennan et al., 1995). The results of this on-going study demonstrate that the selected alfalfa and grass type perennial vegetations can be irrigated with Se-laden saline drainage waters, and not lead to an increase in soluble Se levels in the soil after 2 years. Successfully growing these forages beyond 2 years offers a unique water reuse potential for disposing of Se-laden drainage waters. Without a means to dispose of drainage water containing Se, agricultural land will have to be taken out of production. Land abandonment due to improper use or inappropriate reclamation strategy has been reported in other saline and alkaline soils in Se-enriched mine environments (Sharmasarkar, 1996).

Irrigating crops for 2 years with drainage water did not affect the pH between pre-irrigated and post-irrigated soils; the soils remained typically alkaline (pH 7.7–8.2). The electrical conductivity (EC) increased significantly after 1 year of drainage water irrigation (Table 3). For both crops soil EC increased on the average from 3.60 to 6.57 dS $m^{-1}$ at 0–45 cm and from 5.35 to 6.78 dS $m^{-1}$ at 45–90 cm. Soil EC did not exceed 7.10 dS $m^{-1}$ at 0–90 cm after two seasons of applying drainage water. Based upon the gradual increases in soil EC in the second year of drainage water application, rainfall and extra drainage water applied (more than reported $Et_o$ losses) helped to minimize increases in soil EC after 2 years of drainage water application. Productivity of both crops may be reduced as the level of sodicity in the soil increases and water infiltration decreases with continued use of saline effluent. Increased soil salinity, especially soil sodicity, can lead to increased clay dispersion, decreased soil hydraulic conductivity, and decreased infiltration rates, all of which can have adverse effects on plant growth (Oster et al., 1999). Thus, with eventual increases in soil EC, applying a less saline water at some future time will be necessary for sustaining the drainage water reuse strategy.

After 2 years of irrigation with drainage water there was a significant increase in total and extractable B in soils. In regards to soil B, the extractable fraction is of most significance for the plant. Many plants species are sensitive to extractable B levels greater than 4 mg $kg^{-1}$ (Bingham et al., 1985). Management of extractable B levels in the soil is probably the most important component for any drainage water reuse strategy in central California where B is a primary component of the effluent. The amount of water required to remove a given fraction of B by ponding and sprinkling is at least two times greater than required to remove soluble salts by the least effective method, continuous ponding (Oster et al., 1999). Thus, extractable levels of B in the soil should be constantly monitored.

Total Se levels increased in the soil after application with drainage water for one year (Tables 2 and 3). Significant differences ($P<0.05$) were, however, not observed between first and second year of drainage water application. Concentrations were generally significantly greater at 0–45 cm for both crops each year. Periodic monitoring of the water table levels did not indicate that the water table contributed any soluble Se within the zone of soil sampling. Despite the high volume of Se-laden drainage water applied on both crops during 1999 and 2000 growing seasons, extractable levels of Se did not increase throughout the measured soil profile of 0–90 cm. Because plant accumulation of Se did not have a significant role in extracting the applied Se, losses of extractable Se may have occurred by the following: (1) chemical reduction to elemental Se; (2) immobilization within the rhizosphere; (3) percolation losses beyond 90 cm (extent of soil sampling); and (4) volatilization by microbial and plant activities (Frankenberger and Karlson, 1994; Zayed et al., 2000). All of the above probably contributed to a lower detection of Se in the water extractable form. An increase in residual extractable Se after irrigation with drainage water is a serious concern if soils are eventually leached as a salt and B management strategy. Resulting leachate would contain soluble Se and also would need to be disposed of safely. Monitoring deep percolation of Se is recommended for sites receiving a Se-laden effluent for more than two growing seasons. Future studies should include measurements of different Se species in the soil, e.g., selenite, elemental Se; that may not be accurately detected in the water extractable fraction of Se.

Two years of irrigating with drainage water was an insufficient period to accurately evaluate the threshold soil EC or extractable B levels for both *Salado* alfalfa and alkali sacaton (Maas and Hoffman, 1977). The increased soil salinity and extractable B levels did not affect the yields of both alkali sacaton and *Salado* alfalfa; yields were slightly greater for both crops after a year of applying drainage water. On the average, *Salado* alfalfa and alkali sacaton produced annually 12 and 11 mg $ha^{-1}$, respectively, under saline conditions. Yields from both forage species were not available for non-saline conditions. However, the yields from *Salado* alfalfa and alkali sacaton were almost 50% lower than typical yields reported for alfalfa irrigated with non-saline water in central California (Fresno Department of Agriculture Report, 2001). As long as it is economical viable, planting *Salado* alfalfa is still worthy of consideration for a drainage water reuse strategy because of its known nutritional quality and the growers' familiarity with alfalfa-related crops. Despite grower unfamiliarity with alkali sacaton, it is reportedly more salt tolerant than most legumes (Maas, 1986) and may continue to be as productive

*Table 3.* Selected chemical properties of the soil (0–90 cm) at pre- and post-irrigation of *Salado* alfalfa and alkali sacaton with drainage water in 1999

| Crop | Irrigation | Soil pH | Soil Ec (dS $m^{-1}$) | Concentrations in soil (mg $kg^{-1}$) of: Total Se | Ext. Se | Total B | Ext. B |
|---|---|---|---|---|---|---|---|
| 0–45 cm depth | | | | | | | |
| Alfalfa | Pre | 8.29 [a] a[b] | 3.84 c | 0.85 a | 0.005 a | 47 a | 3.0 b |
| | | (0.06) | (0.62) | (0.07) | (0) | (4) | (0.23) |
| Alfalfa | Post | 8.23 a | 6.27 a | 0.92 a | 0.009 a | 48 a | 5.2 a |
| | | (0.07) | (1.09) | (0.09) | (0) | (3) | (0.35) |
| 45–90 cm depth | | | | | | | |
| Alfalfa | Pre | 7.98 a | 5.10 b | 0.73 bc | 0.008 a | 48 a | 3.2 b |
| | | (0.06) | (0.31) | (0.03) | (0) | (6) | (0.33) |
| Alfalfa | Post | 7.90 a | 6.85 a | 0.68 c | 0.010 a | 44 a | 3.6 b |
| | | (0.05) | (0.95) | (0.06) | (0) | (7) | (0.23) |
| 0–45 cm depth | | | | | | | |
| Alkali sacaton | Pre | 8.24 a | 3.45 c | 0.83 a | 0.006 a | 43 a | 2.2 b |
| | | (0.05) | (0.72) | (0.02) | (0) | (2) | (0.18) |
| Alkali sacaton | Post | 8.19 a | 6.96 a | 0.89 a | 0.010 a | 44 a | 4.0 a |
| | | (0.11) | (1.15) | (0.08) | (0) | (4) | (0.25) |
| 45–90 cm depth | | | | | | | |
| Alkali sacaton | Pre | 8.01 a | 5.61 b | 0.68 b | 0.010 a | 47 a | 4.1 a |
| | | (0.05) | (0.26) | (0.06) | (0) | (6) | (0.34) |
| Alkali sacaton | Post | 7.95 a | 6.61 ab | 0.69 b | 0.009 a | 47 a | 4.2 a |
| | | (0.06) | (0.67) | (0.05) | (0) | (6) | (0.44) |

[a] Values represent the means from 24 samples followed by the standard error in parenthesis.
[b] Values followed by the same letter in columns are not significant at the $P < 0.05$ level for each respective crop at both depths.

under increasing soil salinity . Hence, its palatability and nutritional quality should be evaluated in future animal feed trials.

*Salado* alfalfa accumulated more Se than alkali sacaton for both years (Table 4) and Se tissue levels increased in second year growth of both plant species. High sulfate levels in the water ($\approx$2000 mg $l^{-1}$) reduced the uptake of Se and helped keep the tissue Se concentration under 3 mg $kg^{-1}$ DM. The low tissue Se concentrations allow growers the opportunity to safely consider using these crops as Se-enriched animal forages after irrigation with drainage water (Banuelos and Mayland, 2000). In this regard, cattle and sheep may safely consume seleniferous plant tissues up to 5 mg $kg^{-1}$ without suffering from Se toxicity (Mayland et al., 1989).

Similar to Se levels, B levels were greater in *Salado* alfalfa than alkali sacaton, while Cl levels were greater in alkali sacaton (Table 5). Typical salt toxicity symptoms, e.g., necrosis of leaf margins, were observed on *Salado* alfalfa plants located in low areas of the field where surface salts had precipitated. The relatively low accumulation of B and Cl by both plant species may have contributed to their high survival rate under drainage water irrigation. Plant tissue B and Cl concentrations did not increase significantly with increasing soil EC and extractable B levels after 2 years of water reuse. Although Se is the biological toxicant of concern, it is still uncertain whether B will eventually be the limiting factor in the reuse of saline drainage water of this quality. More information is needed to determine if salt tolerant plants have a

*Table 4.* Selected chemical properties of the soil (0–90 cm) at pre- and post-irrigation of *Salado* alfalfa and alkali sacaton with drainage water in 2000

| Crop | Irrigation | Soil pH | Soil Ec ($dS\ m^{-1}$) | Concentrations in soil ($mg\ kg^{-1}$) of: Total Se | Ext. Se | Total B | Ext. B |
|---|---|---|---|---|---|---|---|
| 0–45 cm depth | | | | | | | |
| Alfalfa | Pre | 7.78 [a] a [b] (0.16) | 5.16 b (0.87) | 0.81 a (0.08) | 0.004 a (0) | 47 ab (4) | 4.2 b (0.30) |
| Alfalfa | Post | 8.01 a (0.01) | 6.40 a (1.00) | 0.84 a (0.09) | 0.005 a (0) | 51 a (6) | 5.2 a (0.33) |
| 45–90 cm depth | | | | | | | |
| Alfalfa | Pre | 7.82 a (0.08) | 5.88 b (0.45) | 0.68 b (0.05) | 0.009 a (0) | 45 b (6) | 4.4 ab (0.34) |
| Alfalfa | Post | 7.81 a (0.10) | 7.10 a (0.70) | 0.66 b (0.03) | 0.008 a (0) | 48 ab (6) | 5.2 a (0.40) |
| 0–45 cm depth | | | | | | | |
| Alkali sacaton | Pre | 7.81 a (0.09) | 5.40 b (0.75) | 0.79 a (0.10) | 0.006 a (0) | 48 a (6) | 3.4 b (0.23) |
| Alkali sacaton | Post | 7.89 a (0.01) | 6.65 a (0.49) | 0.81 a (0.06) | 0.009 a (0) | 47 ab (3) | 5.9 a (0.40) |
| 45–90 cm depth | | | | | | | |
| Alkali sacaton | Pre | 7.79 a (0.05) | 6.24 ab (0.70) | 0.64 b (0.03) | 0.010 a (0) | 42 b (4) | 4.2 b (0.26) |
| Alkali sacaton | Post | 7.72 a (0.01) | 6.48 a (0.60) | 0.63 b (0.06) | 0.009 a (0) | 45 ab (3) | 4.3 b (0.35) |

[a] Values represent the means from 24 samples followed by the standard error in parenthesis.
[b] Values followed by the same letter in columns are not significant at the $P<0.05$ level for each respective crop at both depths.

different response to interactive effects of excess B and salinity. Under high soil salinity, absorption and translocation of B by passive diffusion might be inhibited by transpiration rates (Apaslan and Gunes, 2001), and result in lower B accumulation by plants (Shannon et al., 1997).

## Conclusion

Re-using saline drainage water containing Se and B on alkali sacaton and *Salado* alfalfa may become a supplemental option for making more efficient use of agricultural drainage water. The irrigation of both crops with Se-laden drainage effluent reduced the volume of disposable drainage water and simultaneously produced safe and potentially viable Se-enriched forages. A successful drainage water disposal strategy in central California is more likely to occur if the forage crops accumulate safe levels of Se under increasing sulfate-salinity and B conditions in the soil. Clipping both *Salado* alfalfa and alkali sacaton on a regular basis may help produce more biomass and increase the plants' tolerance to salt and B. While the use of these drainage waters may require only minor modifications of existing irrigation and agronomic strategies, intermittent use of canal water for leaching salts, especially B, and periodically alternating field sites are necessary long-term salt and B management practices that will allow for sustained reuse of poor quality water. Careful attention should be given to depth and quality of the subsurface water table, because shallow groundwater

*Table 5.* Mean tissue concentration of Se, B, and Cl and total dry matter yield of *Salado* alfalfa and alkali sacaton irrigated with drainage water in 1999 and 2000

| | Crop | Concentrations (mg $kg^{-1}$DM) of: Se | B | Cl | Total DM yield[a] (Mg $ha^{-1}$) |
|---|---|---|---|---|---|
| 1999 | | | | | |
| | Alfalfa | 1.7 [b] a [c] | 170 a | 16464 a | 10.1 a |
| | | (0.2) | (44) | (367) | (1.1) |
| | Alkali sacaton | 1.3 b (0.2) | 60 b (11) | 23000 b (501) | 9.1 b (0.8) |
| 2000 | | | | | |
| | Alfalfa | 2.5 a | 157 a | 18765 a | 13.8 a |
| | | (0.3) | (38) | (434) | (1.3) |
| | Alkali sacaton | 1.8 b (0.2) | 64 b (8) | 21006 b (458) | 12.7 b (1.1) |

[a] Includes all cuttings from 6/24–10/23 in 1999 and from 6/15–10/12 in 2000.
[b] Values are means from at least four replicates per five clippings ($n$=20) followed by standard errors in parenthesis.
[c] Values followed by the same letter in columns are not significant at the $P<0.05$ level between crops for each respective year.

consumption is possible for such deep-rooted plants as *Salado* alfalfa. Limitations to drainage water reuse will probably revolve around availability of drainage water for sustained irrigation and most importantly, economics. This includes the economical viability of crop yields after long-term irrigation with drainage water, as well as costs associated with developing the drainage and pumping infrastructure. A sustainable drainage water reuse strategy will require an integrated approach related to irrigation, crop, and soil quality management within the context of being economically viable and environmentally sound.

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